

## GALA SPEECH BY ANDREW WATSON

We live in interesting times, not just at the human timescale, - this century, say versus last, but at the planetary timescale. My fundamental point will be that, even from the perspective of the whole history of the planet, we are at a notable point, that might rank with the major crises of the distant past.

The Earth is 4 1/2 billion years old, and such a large number is a hard concept to get our heads around. As scientists, we find such numbers easy to write and manipulate, using scientific notation for instance. But what does it really mean? Various analogies have been used to help us understand it, but here is one specific to this city of Norwich. Imagine that the time-line of the history of Earth is represented by the railway journey from London to Norwich: it's a hundred miles or so and takes about 2 hours if the trains run to time. The origin of the Earth is at Liverpool Street station in London, and now, 2008, is the buffers at the end of the line. If this railway journey from London to Norwich represents the history of the Earth and you were taking the train, life would have been well established before the train has cleared London, but not life as we think of it today. These were prokaryotes, bacteria, with no individual organism big enough to see. Macroscopic life doesn't get established until very late in the journey, about 7/8ths of the way to Norwich, somewhere around Diss. The human species does not appear until the train is well inside Norwich station, just one carriage length from the buffers at the end of the track. And the industrial revolution – the last 250 years – that occurs in the last centimetre of the journey. During that last centimetre, we – a single species – have seized control of the life support systems of the planet, (the climate, the processes that set the chemistry and composition of its atmosphere and oceans, the vegetable covering of the land) and turned all the dials this way and that – only to realize, that we don't know how to put them back to where they were.

We hear a lot about global warming, but I'd suggest that this is just the currently most immediate symptom of the larger picture. The larger picture is that our species currently appropriates between 20% and 50% of the net primary productivity of the land biosphere, depending how you do the calculation, and an unknown proportion, almost certainly well over 100%, of the sustainable marine production of edible fish. Our population is continuing to grow rapidly, and our consumption per capita is also continuing to grow rapidly. And from these figures it is obvious that we are now, for the first time heading towards, perhaps already have exceeded, the carrying capacity of the planet. At least if we choose to live utilizing the resources as we currently do. We have become a geological force – and the current geological epoch has been named the Anthropocene by nobel laureate Paul Crutzen. We *are* the carbon cycle, the nitrogen cycle, the phosphorus and oxygen and sulphur cycles – we now dominate all the processes that maintain the surface environment of the Earth. Clearly it is not just climate change. Climate change is one of a series of global issues, from pesticides, ozone depletion, acid rain, coming before it and with it and after it, biodiversity loss, energy and food supply worries. These issues all arise together because of the fundamental problem that the human footprint of exploitation is now planet-sized.

It is our ability to individually and collectively imagine and act that has got us into this mess. Our scientific and technical ability steam engines, ships, aircraft, central heating, effective medicine, clean water and all the other trappings and benefits of industrialized humankind. I hope, that our imagination can get us out of it too. If not, then we, and our planet, are in for a long and testing time of crisis.

It may come as a surprise however, to know that there are precedents. Something like this has happened before, not once but at least twice. We are not the first species in which evolution “invented” something that worked so well, but was so foreign to the world at the time, that it brought on a crisis for the whole earth. In fact we are following in the footsteps of several other organisms.

The first we know of was the humble cyanobacterium, or blue-green algae in an older taxonomy. They are much too small to see, though they are still a common and very successful group – half the productivity of the oceans is supported by cyanobacteria, and the coloured scum you may see in a stagnant pond may be them. But at three billion years or so ago, a third of the way through our train journey, a single one of these cells – one cell, too small to see, and with a lifetime measured in days or weeks, stumbled on a trick: it “invented” – that is the closest single word in English to describe the process of evolution – the art of photosynthesis, producing oxygen as a by-product.

It was able to use this to get energy from the sun, and carbon from carbon dioxide, using just water and carbon dioxide as substrates. And since water was already an absolute requirement for life, and carbon dioxide was plentiful in the atmosphere at that time, it was phenomenally successful. Soon its descendants spread throughout the oceans. But the by-product, oxygen, was a problem. It was a reactive gas that was toxic to almost all the other lifeforms. Up until this point, there had been no oxygen at all in the atmosphere. Now oxygen is a very dangerous gas. It is highly reactive and potentially very useful to life if it can deal with it, but to organisms that had never been exposed to it before it was like a disinfectant – quickly lethal. We can survive in a high oxygen environment because our remote ancestors, dating from that time, evolved protection mechanisms against the intracellular damage from free radicals associated with oxygen.

At first the oxygen was quickly taken up by reaction with rocks, but eventually, about 2.4 billion years ago, it started to build up in the atmosphere. When that happened, the other creatures at the surface of the Earth had to learn to live with oxygen, move underground, or die.

Furthermore it altered the climate of the planet, reacting with greenhouse gases, chiefly methane, in the atmosphere and cooling it drastically, plunging the Earth into a deep and terrible ice age – one of the deepest and glaciations that the Earth has ever experienced. This was a climate catastrophe that makes global warming, what we are doing to the earth today, look like a warm summer day by comparison.

A sheet of ice covered the planet, land and ocean, from poles to equator – a “snowball earth”, in which nothing could live except in small refuges, near hot springs, or deep in the ocean at the hydrothermal vents.

Eventually, after tens of millions of years, the climate stabilized (we don’t know exactly why, or whether it was bound to happen or just a lucky accident). A new planet emerged. Entirely new, with oxygen, a new gas in its atmosphere that, one day, would enable the existence of multi-cellular life, dinosaurs, trees, whales, elephants and humans. All the many forms, diverse and beautiful, of what *we* usually think of as life were enabled by that experiment that so nearly went catastrophically wrong. We owe our existence to that ancestral cyanobacterium.

The “earth system” was eventually able to recover from this assault, to evolve new systems to cope with, and take advantage of, the new, toxic but very energetic gas. From the fact that life on Earth has apparently survived for so long and despite such disasters, people sometimes infer that it is indestructible – the Earth will always take care of itself, so we can’t seriously harm it today. But that is false logic, a mistaken impression. At the basic microbial level the Earth system is tough, yes, but its elaboration and progress to complex life may actually have been an unlikely outcome. However, had it not happened that way, we – you, me, everyone, would not be here to wonder about it. Our existence is dependent on the fact that it did survive and progress, even if it was just good luck. We shouldn’t take the favourable outcome of past events, on which however our very existence is dependent, as an indication of the likely outcome of the present crisis.

Second, the Earth survived, adapted, and eventually was strengthened, but it did this by blind luck and evolution, without the quickness of human imagination – though I think you can say that there is a kinship between the “designs” of the human imagination and the designs of evolution. But evolution is *slow*: it took a tens to hundreds of millions of years for the Earth system to fully recover from the oxygen assault. Evolution cannot plan ahead – the cyanobacteria could not foresee what the consequence of their invention would be. If they could have done, they would never have done it. We can plan ahead and we ought to be able to avoid such a disaster.

Ought to. But can we really? Our intelligence and imagination is double-edged. It has given us the power to destroy ourselves and most of the life on earth, either quickly as in nuclear holocaust, or slightly less quickly by screwing up the life support systems of the planet. It has also given us the ability to foresee what may happen and therefore to take steps to prevent it. James Lovelock has personalized the Earth system, giving it a name and calling it Gaia, and I think that can be a very useful idea. We can be Gaia’s consciousness, her source of inspiration, foresight, intelligence, morality and creativity, but we can be also be the cancer that kills her, or at least severely maims her. Either way, the genie of the human imagination, now supercharged and fossil-fueled, is out of the bottle and will not be put back.

What of the role of science, and in particular network science and the study of complex systems, in this? Science has played its part in getting us into the problem, but science can be a good part of our salvation too. In particular, we need to better understand the Earth system, the coupled climate / biogeochemical / human system. It exhibits whole-system behaviour that is difficult to understand if we look at the individual parts alone. We have a beautiful example of this in the records of the last million years of climate change revealed in Antarctic ice cores. They show the response of the whole system, the atmospheric CO<sub>2</sub> and methane concentrations as well as the physical climate system, responding non-linearly with an elaborate choreography to the small variations in Earth’s orbital forcing. We’ve known about this for 30 years but we still don’t fully understand this. And there is the behaviour of some the sub-sections of this system, the ecosystems and the human system, which are ripe for study as networks.

I’d like to think that science alone could get us out of this problem and lead us to the sunny uplands of a global human society in harmony and balance with the rest of nature on the planet. I don’t think this is going to happen through science alone. It seems to me that there remains a fundamental gap between what scientists understand and what the wider public think. The quality of the environmental debate is poor, with people shouting past each other, exaggeration of certainty on both sides.

I think that we scientists have a duty to write and speak more clearly to the public, to convey to them both what we are pretty certain about and what we are less certain about, and also about the beauty of the planet we have now, and its long, its very long history that we are privileged to be able to observe, and which we can learn a great deal from.

We are not certain about all the effects of the current crisis, but we can be sure of this: We are now in charge of Earth’s life support system whether we like it or not. We had better learn, and quickly, how to adjust those dials to keep the planet habitable. That is why we are now at a geologically significant crisis point, as significant as any in Earth history.

Andrew Watson, June 2008